REMARKS/ARGUMENTS

In the Office Action, Claims 1-30 are pending of which Claims 7, 9 and 21-25 are withdrawn, and Claims 1-6, 8, 10-20 and 26-30 are rejected.

I. Claim Rejections

Claims 1-5, 8, 10-12, 15-18 and 26-29 are rejected under 35 U.S.C. 102(a) as being allegedly anticipated by Xiong (WO03/007438). Claims 6, 19-20 and 30 are rejected under 35 U.S.C. 103(a) as being unpatentable over Xiong (WO03/007438) in view of U.S. Patent No. 6,009,110 to Wiechmann et al. Claims 13-14 are rejected under 35 U.S.C. 103(a) as being unpatentable over Xiong (WO03/007438) in view of U.S. Patent Publication No. 2003/0039274 to Neev et al.

In response, Applicant submits a declaration under 37 C.F.R. 1.131 by the inventor Wang Long Zhou of the instant application. As evidenced by the affidavit, prior to January 23, 2003, a full disclosure was set out in a patent proposal with a description of the claimed invention with figures. The disclosure describes the claimed hybrid Q-switch device of the present invention.

35 U.S.C. 102(a) states that:

A person shall be entitled to a patent unless –

> the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, <u>before the invention thereof by the applicant</u> for a patent.

The Xiong reference (WO03/007438) has a publication date of January 23, 2003. It is evidenced by the affidavit that the claimed subject matter of the instant application predates the publication date of Xiong. Therefore, the cited reference of Xiong is improper in a 35 U.S.C. 102(a) rejection of the claims.

Because the dependent claims recite further additional/unique elements, the 103(a) rejections of the dependent claims citing Xiong in combination with other references is improper based on the improper 102(a) rejection of the independent claims.

Accordingly, Applicants request withdrawal of the 35 U.S.C. 102(a) rejection of claims 1-5, 8, 10-12, 15-18 and 26-29 as being anticipated by Xiong (WO03/007438). Applicants further request withdrawal of the 35 U.S.C. 103(a) rejection of claims 6, 19-20 and 30 as being unpatentable over Xiong (WO03/007438) in view of Wiechmann et al., and withdrawal of the 35 U.S.C. 103(a) rejection of claims 13-14 as being unpatentable over Xiong (WO03/007438) in view of Neev et al.

II. Conclusion

In view of the aforementioned remarks and amendments, the Applicants believe that each of the pending claims is in condition for allowance. Accordingly, Applicants respectfully request allowance of claims 1-6, 8, 10-20 and 26-30. If, upon receipt and review of this amendment, the Examiner believes that the present application is not in condition for allowance and that changes can be suggested which would place the claims in allowable form, the Examiner is respectfully requested to contact Applicant's undersigned counsel at the number provided below.

Please charge any additional fees that may be due, or credit any overpayment of same, to Deposit Account No. 03-1250 (Ref. No. 040017U0008).

Respectfully submitted,

Date: June 22, 2007

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s):	Wang Long Zhou	**Examiner:**	Dung T. Nguyen
Serial No:	10/766,706	**Art Unit:**	2828
Filed:	January 27, 2004	**Docket:**	040017U0008
For:	HYBRID Q-SWITCH DEVICES, LASERS USING THE SAME, AND METHOD OF OPERATION	**Dated:**	June 22, 2007

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. 1.131

Sir:

I, Wang Long Zhou, hereby declare and say that:

1. I am the Inventor of the instant application;

2. Lambda Solutions, Inc. is the assignee of the entire right, title and interest in the above-identified above patent application, Serial No. 10/766,706 filed January 27, 2004, which describes my invention comprising a hybrid Q-switch device;

3. Prior to January 23, 2003, a full disclosure was set out in a patent proposal with a description of the claimed invention with figures. The disclosure describes the claimed hybrid Q-switch device. A copy of the disclosure and figures marked "Applicant's Exhibit A" is enclosed with the dates removed. I was responsible for authoring the disclosure and have first hand knowledge of the information provided in the disclosure; and

4. I further declare that all statements made hereinabove are of my own knowledge and are true and that all statements made on information and belief are believed by me to be true. Further, I declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 8 of the United States Code and that such willful false statements may jeopardize the validity of a Patent Application or any patent issuing thereon.

Respectfully submitted,

Dated: 6/22/2007

By: [signature]
Wang Long Zhou

#1202441 v1

Hybrid Q-switches and Lasers Using the Same

WLZhou / Lambda Solutions, Inc. /

Field: The invention is related to lasers, particularly, to methods of Q-switching.

Background: Many laser applications, such as remote sensing, radar, and laser-induced breakdown, demand high peak laser power. In general, for a certain pulse energy, the shorter the duration of the pulse, the higher the peak power. Although ultra-short (<100ps, $1ps=10^{-12}s$) laser pulses can be generated through complicated mode-lock method, the energy per pulse is very normally very low due to intrinsically high pulse repetition rate (>MHz). For high peak laser power, Q-switching is the most-often the trigger of choice because its repetition rate could be as low as 1Hz.

There are many different Q-switch methods and they are generally divided into two categories, i.e., active and passive. Basically, active Q-switch is controllable on pulse reproduction but bulky and expensive, while passive Q-switch is small and inexpensive, but lack of control.

The most widely used active Q-switches are electro-optic (EO) and acoustic-optic (AO) Q-switches. They require complicated electronic control circuist and bulky EO or AO crystals (20~30mm in length). The advantages of active Q-switch is the free control of pulse repetition rate and the high pulse reproducibility (low time jitter and high pulse-to-pulse stability). The pulse duration is largely dependent on the rise-time of the electronic control signal and the corresponding response of the EO or AO crystal. EO Q-switches are able to generate sub-10ns (nano-second, $10^{-9}s$) pulses while AO Q-switch normally delivers sub-100ns pulses.

Rotating a cavity mirror or a chopper is also an active way to Q-switch a laser. It is relatively simple and has been utilized in the early stage of the laser history and is now virtually obsolete due to the difficulty of obtaining high peak pulse with this method.

Passive Q-switches only need a saturable absorber that is placed inside laser cavity. The absorber prevents the laser from lasing by highly absorbing the lasing wavelength until it is saturated. Once saturated, the absorber suddenly becomes transparent to the lasing wavelength so that the energy stored in the laser medium is triggered to release in a short period to form a short laser pulse. The absorber will then recover to its initial state and be ready for the next cycle. A microchip Nd:YAG laser with Cr^{4+}:YAG absorber has been demonstrated to generate pulses shorter than 300ps (US patent 5,394,413).

Passive Q-switches are simple and are able to generate sub-ns or even shorter pulses. However, the timing of the onset of the absorber becoming transparent fluctuates upon inevitable variations of pumping power, pumping wavelength, temperature, and other cavity related parameters. The pulse repetition rate changes along with pumping power and is also dependent on various parameters of laser medium, absorber, and cavity design. Therefore, a laser with a passive Q-switch is lack of control in pulse generation in terms of repetition rate and pulse-to-pulse time jitter and energy stability. Furthermore, under continuous-wave pumping, the repetition rate of a passive Q-switch laser is typically way too high for getting highest peak power. Also, a laser with a passive Q-switch must operate near the threshold in order to prevent the occurrence of sub-pulses, that greatly limits the laser output.

The disadvantages of a passive Q-switch could be largely eliminated by an active Q-switch and vise versa. In some degree of extent, the active and passive Q-switches are characteristically complimentary. The present invention is about an innovative hybrid Q-switch that combines both active and passive system physically and characteristically.

Object: One aspect of the present invention is to provide a hybrid Q-switch comprising an active and passive means of loss modulation. Said active and passive means are, respectively, an active element, such as state-of-art EO and AO Q-switches and rotating chopper, etc., and a saturable absorber, such as a piece of Cr^{4+}:YAG crystal, a semiconductor material, or a semiconductor-doped-glass material, etc.

Another aspect of the present invention is to provide a microchip laser for generating repetition-rate-controllable pulse with pulse width ranging from 50ps to 10ns. The said microchip laser comprises two mirrors forming a resonant cavity, a solid-state laser medium, such as Nd:YAG, Yb:YAG, and Nd:YVO_4, and a chopper/absorber hybrid Q-switch.

Figures: (Same or similar elements in different figures are labeled with the same number for simplicity.)

Fig. 1 A prior art laser with an active Q-switch.
Fig. 2 A prior art laser with a passive Q-switch (saturable absorber).
Fig. 3 A laser with a hybrid Q-switch according to the present invention.
Fig. 4 A microchip laser with a chopper/absorber hybrid Q-switch according to the present invention.

Fig. 1

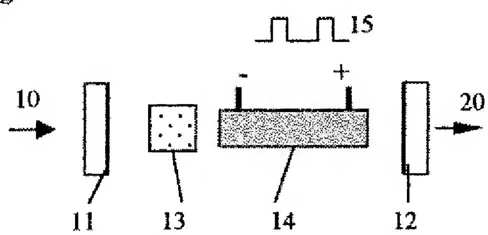


Fig. 2

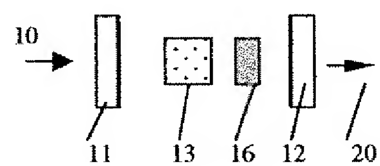


Fig. 3

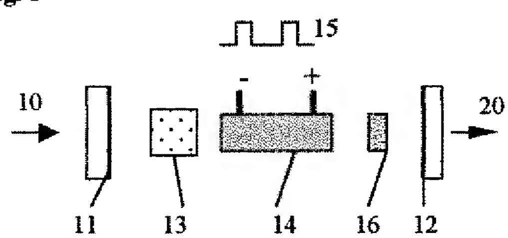
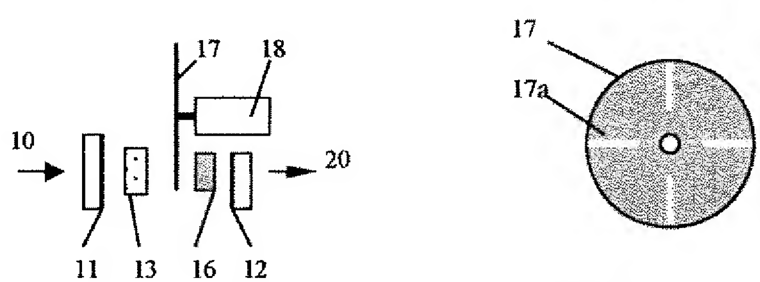


Fig. 4



Description: Fig. 1 shows a typical active Q-switch laser. Its cavity comprises two mirrors 11 and 12, a laser medium 13, and an active Q-switch 14. It's end-pumped with pump source 10. The pump source could be a semiconductor laser, a solid-state laser, or a gas laser. If pumped with flash lamp, then the laser cavity and the laser medium would normally be designed for side pumping. The active Q-switch 14 could be an acoustic-optic (AO) Q-switch that utilizes a bulk AO crystal, such as quartz and TeO2, and it requires a high-power radio frequency source to generate acoustic wave propagating through the crystal to diffract out lasing wavelength. Lasers with AO Q-switch can emit sub-50ns pulses. For sub-10ns pulses, electro-optic (EO) Q-switch would be more often being employed. In an EO Q-switch, an EO crystal, such as KDP, BBO, and LiNbO3, would be used. The loss modulation is realized by changing crystal's birefringent characteristic through applying kilovolt electric pulses on the crystal. The crystal could be several centimeters long for lowering high voltage requirement.

For explanation purpose, we assume an EO Q-switch is adopted in the laser of Fig. 1. The EO Q-switch 14 is driven by high-voltage electric pulse 15 through +/- electrodes. The laser pulse exited from the laser at lasing wavelength is indicated as 20. The pulse repetition rate can be precisely defined by adjusting the frequency of the electric pulse. The duration of the laser pulse is largely dependent on the rise time (~several ns) of the electric pulse. An EO or AO Q-switch is able to produce stable and well-defined pulses. However, it is bulky and costly and needs complicated electronics, and is not suitable for obtaining pulses shorter than several nano-seconds.

In the past decade, passive Q-switches have been extensively studied and already applied in the commercial laser products. It uses a saturable absorber, such as Cr^{4+}:YAG, to absorb the intended lasing wavelength to prevent lasing for a period and then the absorber gets saturated and suddenly becomes transparent so the lasing is enabled. The absorber will recover to the unsaturated state before the laser medium is pumped to an extent sufficient for another lasing.

Passive Q-switch is simple, compact, and low lost, and does not require electronic power supply. Fig. 2 shows a typical passive Q-switch laser with a saturable absorber 16. The absorber 16 is a material that is absorption-saturable to the intended lasing wavelength. It includes Cr^{4+}:YAG, Cr-doped forsterite, Cr-doped gadolinium scandium gallium garnet, saturable semiconductor material, and semiconductor-doped glass, etc. For example, the saturable absorption for Cr^{4+}:YAG is ranging from 900nm to 1200nm.

Studies have revealed that passive Q-switch could be used to produce pulses in pico-second (ps) regime. Zayhowski (US patent 5,394,413) demonstrated a Nd:YAG/Cr^{4+}:YAG microchip laser with <300ps pulse output. A Nd:YVO_4 microchip laser with 56ps pulse output is reported by Braun et al (Opt. Lett., v22 p381, 1997), where a semiconductor anti-resonant Fabry-Perot saturable absorber is utilized.

Although a passive Q-switch could generate sub-ns pulse, the energy per pulse is very limited (typically under 10uJ) due to intrinsically high repetition rate and near threshold pumping. Near threshold pumping is required for preventing the occurrence of sub-pulses. Besides, compare to active Q-switch, pulses from passive Q-switch normally have larger time jitter and peak-to-peak power fluctuation, because the timing of the onset of the absorber becoming transparent fluctuates upon the variations of pumping power, pumping wavelength, temperature, and other parameters. This latter problem is addressed by coupling the triggering of the passive switch to an active Q switch.

According to the present invention, a hybrid Q-switch is provided that comprises means of both active and passive loss modulations. Fig. 3 is a laser embodied with a hybrid Q-switch consisting of an active Q-switch 14 and an absorber 16. The sequence of laser function is as follow. The laser medium 13 is pumped by pumping source 10 for a period and gets population inverted (gain), and then the active Q-switch 14 opens (i.e., reduce its loss to the minimum) when an electric pulse (15) comes. The laser will then starts lasing at noise level at the intended lasing wavelength that will be partially absorbed by the absorber 16. The absorber 16 will be finally saturated and, at the same time, the total cavity loss will drop down to the minimum so that a laser pulse will be produced. The laser pulse consumes all or most of the gain stored in the laser medium so the lasing will discontinue and the absorber 16 will recover to its initial state. Sooner or later the active Q-switch will also be closed to complete a full pulsing cycle. The time window of the active Q-switch being opened equals the duration of the electric pulse 15 and should be narrow enough to avoid second pulsing.

There is a time interval between the opening of the active Q-switch and the onset of saturation of the absorber. The laser will fire a pulse only after the absorber being saturated. Therefore, the duration of the laser pulse will largely depend on the passive absorber but not the active Q-switch. On the other hand, because the opening of the active Q-switch happens after the laser medium being pumped to a certain or

even saturated gain level, the said time interval will be much more regulated than the timing of the saturation onset of a free-running passive Q-switch laser.

As a result, a laser with such hybrid Q-switch will produce pulses having the shorter duration as with those from a passive laser and having the high reproducibility as those from an active laser. The pulse repetition rate will be controllable and can be adjusted to a value for the highest peak power or the maximum efficiency. Also, by adjusting the opening time window of the active Q-switch, the laser will work well above threshold without the occurrence of a sub-pulse. The hybrid Q-switch of the present invention combines the advantages of both active and passive Q-switches and eliminates their drawbacks.

In addition, the hybrid Q-switch is not mechanically more complicated than the corresponding active Q-switch. In fact, due to the addition of passive loss modulation, the depth of active loss modulation could be reduced so that a shorter EO/AO crystal or lower-voltage electronics can be used. In consequence, a hybrid Q-switch could be more compact and less expensive than the corresponding active Q-switch and meets the requirement of less total power needed to create a high "peak" power laser pulse.

Back to Fig. 3, the absorber 16 can be placed at the right side of the active Q-switch 14 as shown in the figure. It can also be put at the left side or even bonded together with the active Q-switch crystal.

While the above embodiment creates many of the advantages and meets the minimal requirements of the invention, i.e., less total power needed to create a high "peak" power laser pulse, nevertheless, a hybrid Q-switch based on an EO or AO active Q switch is still basically bulky and expensive. Another hybrid Q-switch according to the present invention is the combination of a fast rotating chopper and a saturable absorber. A rotating chopper is simple and the corresponding power consumption is negligible. The chopper could be very thin (<0.5mm) so that a laser with such a hybrid Q-switch will be almost as compact as one with only a saturable absorber. A motor that drives the chopper can go easily over 250 turns per second. Adding more opening holes/slits on the chopper can increase the repetition rate. (*A rotating chopper or mirror has been used to Q-switch lasers in the early stage of the laser history. The advantage of this method is simplicity and lossless when totally opened or aligned. However, it has been revealed that a laser Q-switched with only a rotating element is not able to produce short-duration high-peak-power pulse due to slow evolution from edge cut to entire open (or exactly aligned). The laser pulse is actually formed before entire open and so it suffers high loss and can not take the above-mentioned loss less advantage and therefore by itself will not meet the requirements of the invention*)

However, a chopper/absorber hybrid Q-switch, does serve to create a repitive and reproducible trigger for a passive Q switch based on an absorbing crystal since only during the open gate will light pass . moreover, the laser will not lase during the chopper early high-loss opening stage until the absorber is saturated anyway. Therefore, a laser with this hybrid Q-switch suffers much less loss and can produce much shorter and higher-peak pulses than that with chopper-only Q-switch.

Fig. 4 shows a microchip laser embodied with a chopper/absorber hybrid Q-switch. 'Microchip laser' is a term means that the laser medium is thin (<couple mm) and is typically diode-pumped and the laser has a short cavity and so is extremely compact. For further compactness, the pump-side face of the laser medium (13) is coated for high reflection at the lasing wavelength and so it serves as one cavity mirror (11). The same thing can be done to the output-side face of the absorber 16 if it is located at the most end of the output side as shown in Fig. 4. The absorber 16 can also be placed adjacent to the laser medium and they even can be bonded together. In another embodiment, a single YAG crystal co-doped with Nd^{3+} and Cr^{4+} is used that acts as both laser-gain medium and saturable absorber. All the alternations mentioned here are also applicable to the embodiment of Fig. 3.

Refer to Fig. 4, the chopper 17 is driven by a micromotor 18. The diameter of the chopper is preferably under 4cm for microchip laser. There will be at least one opening hole or slit on the chopper to regulate pulse generation. On the right side of Fig. 4 is a chopper example with four opening slits (17a). The width of each slit should be larger than the laser beam diameter, and preferably, around twice of the laser beam diameter. Besides, the width of each slit should be narrow enough for avoiding second pulsing. In some cases, the width of slits could be made adjustable through special means or ways, e. g., by overlapping two identical choppers so that the slits of each other could be adjusted to crossover more or less. Basically, the faster the evolution from edge cut to entire open, the better. Therefore, it is favorable to use a chopper of diameter as large as possible. In a high power laser that is usually of larger dimensions, a chopper with diameter larger than 4cm might be more preferred.